A-LEVEL CHEMISTRY • EXERCISE SHEET

29.2 Characteristic organic reactions

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

KEY WORDS electrophilic substitution 亲电取代 • addition–elimination 加成消去 • characteristic organic reactions 有机反应类型 • free radicals 自由基 • electrophiles 亲电试剂

Objective

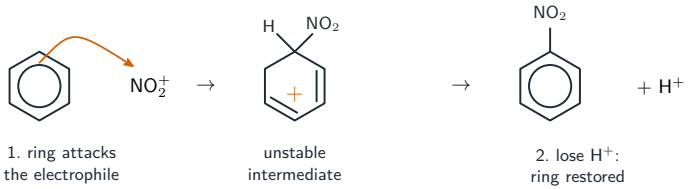
Build the skills to answer exam questions on **characteristic organic reactions** 有机反应类型 — classifying a reaction by its type and the kind of reagent involved.

You must be able to:

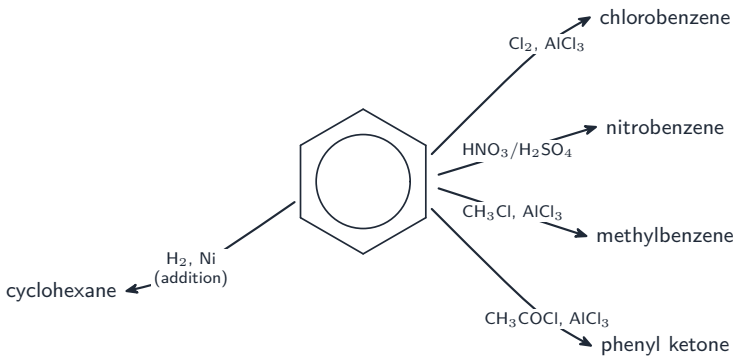
- classify reactions as addition, substitution, elimination, hydrolysis, condensation, oxidation, reduction or polymerisation
- classify reagents as **electrophiles** 亲电试剂, **nucleophiles** 亲核试剂 or **free radicals** 自由基
- describe the two new mechanism types: **electrophilic substitution** and **addition–elimination**

1 Worked examples

■ Naming the reaction type



Electrophilic substitution: an electrophile replaces a ring hydrogen — the characteristic reaction of benzene



Characteristic reactions of the benzene ring

- **electrophilic substitution** — an electrophile replaces an H on a benzene ring (e.g. nitration).
- **nucleophilic substitution** — a nucleophile replaces a leaving group (e.g. OH^- + halogenoalkane).
- **addition** — a π bond opens and two groups add on (e.g. Br_2 + alkene).
- **addition–elimination** — a group adds, then a small molecule leaves (e.g. 2,4-DNPH, acyl chlorides).

Reagent types: electrophile = electron-pair **acceptor**; nucleophile = electron-pair **donor**; radical = species with an unpaired electron.

2 Practice

2.1 State what is meant by an **electrophile**. [1]

2.2 Classify the reaction of bromine with ethene (an alkene). [1]

3 Exam-style questions

3.1 The reaction of OH^- with bromoethane is best classified as: [1]

- **A** electrophilic addition
- **B** nucleophilic substitution
- **C** electrophilic substitution
- **D** free-radical substitution

3.2 Which species is a nucleophile? [1]

- **A** NO_2^+
- **B** H^+
- **C** $:NH_3$
- **D** $Cl^\bullet$

3.3 For each reaction, name the **type** and the **reagent class**: [3]

(a) benzene + NO_2^+ → nitrobenzene + H^+

(b) ethene + Br_2 → 1,2-dibromoethane

(c) an ester + water → a carboxylic acid + an alcohol

3.4 Explain why benzene undergoes **substitution** rather than **addition**, unlike an alkene. [2]

3.5 Four reactions of propene and its derivatives are shown.

- **I** $CH_3CH=CH_2 + Br_2 \rightarrow CH_3CHBrCH_2Br$
- **II** $CH_3CHBrCH_3 + KOH(aq) \rightarrow CH_3CH(OH)CH_3 + KBr$
- **III** $CH_3CHBrCH_3 + KOH$ in ethanol $\rightarrow CH_3CH=CH_2 + KBr + H_2O$
- **IV** $CH_3CH(OH)CH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$

(a) Classify each reaction by type. [4]

(b) For **I**, name the attacking species and explain how a non-polar bromine molecule comes to attack an alkene. [3]

(c) Reactions **II** and **III** use the same reagent on the same compound but give different products. Explain what decides which happens. [2]

(d) Name a suitable oxidising agent for **IV**, and state what you would see. Explain why the product cannot be oxidised further. [3]

Solutions

2.1 an electron-pair acceptor / a species that is attracted to a region of high electron density.

2.2 electrophilic addition.

3.1 B. OH^- is a nucleophile and it replaces the bromine — nucleophilic substitution.

3.2 C. $:NH_3$ has a lone pair to donate — a nucleophile.

3.3 (a) electrophilic substitution; electrophile
(b) (electrophilic) addition; electrophile
(c) hydrolysis (substitution); water/nucleophile.

3.4 benzene's delocalised π system is very stable; substitution keeps the stable ring intact, whereas addition would destroy the delocalisation, so substitution is favoured.

3.5 (a) **I** electrophilic addition; **II** nucleophilic substitution; **III** elimination; **IV** oxidation.
(b) The **electrophile** is bromine, Br_2, acting as $Br^{\delta+}$–$Br^{\delta-}$. The high electron density of the π bond repels the electrons in the approaching Br_2, inducing a dipole; the now $\delta+$ bromine atom is attacked by the π electrons.
(c) The **solvent and conditions**: aqueous KOH favours substitution, giving the alcohol; hot KOH in ethanol favours elimination, giving the alkene.
(d) Acidified potassium dichromate(VI), $K_2Cr_2O_7/H_2SO_4$; the solution turns from orange to green as $Cr_2O_7^{2-}$ is reduced to Cr^{3+}. Propanone is a **ketone** — its carbonyl carbon carries no hydrogen, so further oxidation would need a C–C bond to break, which this reagent cannot do.